Comparative Study of Hydraulic Design of Orifice Spillway between IS 6934:1973 & IS 6934 (Draft Code 2010)

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Abstract—Spillways, generally the ogee-crested type, are sometimes provided with a breast wall from various considerations. This spillway is widely used in Hydro power generation scheme. The hydraulic design of such spillway includes Profile of the spillway crest including the upstream and downstream quadrants, and Profile of the bottom surface of the breast wall. For the purpose of preliminary design, Bureau of Indian Standard had introduced IS 6934 in year 1973. The standard was then revised to incorporate the latest practices being followed in the field, the major changes being in dealing with ogee profile for spillway with breast wall. This research is an attempt to strike out the difference in the design between the IS 6934:1973 and Draft Indian standard (2010).For this purpose two Dams namely Nimoo Bazgo (Jammu & Kashmir) & Sewa II (Jammu & Kashmir), situated in India were examined and conclusions were then made.

I. INTRODUCTION

The spillway is among the most important structures of a dam project. It provides the project with the ability to release excess or flood water in a controlled or uncontrolled manner to ensure the safety of the project. Various types of spillways include overflow, shaft or morning glory, siphon, chute, side channel, tunnel spillway, etc.

The ogee-crested type, are sometimes provided with a breast wall from various considerations such as increasing the regulating storage of flood discharge, reducing the height of the gate, minimizing the cost of gate operating mechanism, etc. The spillway would allow the setting of its crest at significantly lower elevation, yet retaining the choice of a high dam for creating head for power generation.

Orifice spillways have been widely recognized as the most appropriate especially for run-of-the river projects for handling both flood releases and flushing of sediment. Orifice spillway is essentially large capacity outlet provided in the dam and controlled by gates.

The IS 6934 (Hydraulic Design Of High Ogee Overflow Spillways - Recommendations) standard was first published in 1973 and revised in 1998 for alteration in hydraulic design of high ogee spillway, whereas this Draft code incorporates the latest practices being followed in the field, the changes dealing with ogee profile for spillway with breast wall.

II. OGEE PROFILE FOR SPILLWAYS WITH BREAST WALL

The hydraulic behavior of orifice spillway changes with the varying reservoir levels. The flow is free flow for reservoir water levels below the top of the orifice opening. For higher water levels the flow is orifice flow. The spillway crest profile is required to be designed for orifice (pressurized) flow.

III. HYDRAULIC DESIGN BASED ON IS 6934: 1973

A. *UPSTREAM QUADRANT*

The upstream quadrant may conform to an ellipse with the equation:

$$\frac{{X_3}^2}{{A_3}^2} + \frac{{Y_3}^2}{{B_3}^2} = 1 \qquad (1.1)$$

Where,

$$A_3 = 0.541\, D\, (H_d/D)^{0.32} \qquad (1.1\text{ a})$$

$$B_3 = 0.3693\, D\, (H_d/D)^{0.04} \qquad (1.1\text{ b})$$

B DOWNSTREAM PROFILE

The downstream profile may conform to the equation:

$${X_4}^{n_4} = K_4\, {H_d}^{n_4-1}\, Y_4 \qquad (2.1)$$

Where,

$$K_4 = 0.44 - 0.025\,\frac{H_d}{D} \qquad (2.1\text{ a})$$

$$n_4 = 1.782 - 0.0099\,(\frac{H_d}{D} - 1)$$

C BOTTOM PROFILE OF THE BREAST WALL

The bottom profile of the breast wall may conform to the equation:

$$X_5 = \frac{K_5}{{n_5}^{2.4}}\, {Y_5}^{2.4} \qquad (3.1)$$

Where,

$$K_5 = 0.541\, D\, (H_d/D)^{0.32} \qquad (3.1\text{ a})$$

$$n_5 = 0.4\, D \qquad (3.1\text{ b})$$

The upstream edge of the breast wall is in line with the upstream edge of the spillway and the downstream edge is in line with the spillway crest axis, as shown in fig 2

IV. HYDRAULIC DESIGN BASED ON IS 6934 (DRAFT CODE)

A UPSTREAM QUADRANT

The upstream quadrant may conform to the ellipse:

$$\frac{{X_1}^2}{{A_1}^2} + \frac{{Y_1}^2}{{B_1}^2} = 1 \qquad (4.1)$$

The magnitudes of A_1 and B_1, are determined with reference to the parameter P/H_d, from the graphs, given in Fig. 3

B DOWNSTREAM PROFILE

The crest profile generally follows the equation

$$X^2 = 4\,H_c\,Y \qquad (4.2)$$

C BOTTOM PROFILE OF THE BREAST WALL

A profile in the form of quarter of an ellipse in provided bearing the equation

$$\frac{X^2}{{A_2}^2} + \frac{Y^2}{{B_2}^2} = 1 \qquad (4.3)$$

Where,

A_2 = width of semi-major axis i.e. the width of breast wall,

B_2 = width of semi-minor axis which governs the steepness of the profile.

X and *Y* are the coordinates of the profile.

Usually steep profiles yield increased coefficient of discharge, whereas flat profiles tend to reduce the discharging capacity. However, negative pressures increase as the profile becomes steeper. High negative pressures with cavitation index below 0.2 are undesirable.

The roof profiles of orifice opening are usually steel lined/constructed in high strength concrete to avoid cavitation damage.

V. SIZE OF THE ORIFICE SPILLWAY

The IS 6934:1973 kept silent about the size of orifice spillway but some guideline had been incorporated in the recent draft code.

The Flushing used to be carried out previously by providing small sluices of the size of 3 m x 4 m or so at very low level. However, it was realized that these sluices were effective only locally.

Also, there was a tendency of choking of sluices within a short period. Large openings of the size of 6 - 15 m (W) × 10 - 21 m (H) are required to be located 30 - 40 m below the full reservoir water level and as near the river bed as possible for flushing of the reservoir.

VI. CASE STUDIES

To compare the difference in the hydraulic design of Spillway of two Dams have been considered, and they are mentioned in Table no. 1 along with the basic hydraulic details.

VII. RESULTS

The results obtained are tabulated in table no 2. The profile of Spillway for both the dams using both the codes had been plotted in fig no 4.

VIII. CONCLUSIONS

Based on the results from this experimental work, following conclusions were made:

– The variation in design of upstream profile is quite low between designs of both the code.

– The downstream profile becomes much steeper when using IS 6934:1973.

– The bottom of breast wall tends to become steeper for IS 6934:1973 but the extent is quite small.

ACKNOWLEDGEMENT

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REFERENCES

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NOTATIONS

The following symbols are used in this paper:

A_1, A_2, etc.	Horizontal dimension defining upstream quadrant of the crest,
B_1, B_2 ,etc.	Vertical dimension defining upstream quadrant of the crest,
D	Net opening for the spillway with breast wall,
G_O	Gate opening,
H	Head of overflow,
H_c	Head from reservoir level up to the center line of the opening of the gate,

H_d	Design head,
K_1 ,K_2, etc.	Variable parameters,
n_1'n_2' etc.	Variable parameters,
P	Height of the spillway crest measured from the river bed,
X, X_1, X_3, Y, Y_1, Y_3,, etc.	Co-ordinates of the profile

Dam	D (m)	H (m)	P (m)	Span nos	Span Width (m)	Discharge (cumec)
Nimoo Bazgo (Jammu & Kashmir)	9	23.5	28	5	7	4500
Sewa II (Jammu & Kashmir)	10.8	29.5	9.7	4	7	4020

Table. 1 Dam information

Based on IS 6934: 1973			Based on IS 6934:Draft Code		
Spillway Profile		Brest wall	Spillway Profile		Brest wall
Upstream	Downstream	Bottom profile	Upstream	Downstream	Bottom profile
Nimoo Bazgo					
$\frac{X^2}{6.62^2} + \frac{Y^2}{3.45^2} = 1$	$X^{1.77} = 4.21\,Y$	$X = 0.31\,Y^2$	$\frac{X^2}{6.35^2} + \frac{Y^2}{3.76^2} = 1$	$X^2 = 76\,Y$	$\frac{X^2}{5.6^2} + \frac{Y^2}{2^2} = 1$
Seva II					
$\frac{X^2}{8.06^2} + \frac{Y^2}{4.15^2} = 1$	$X^{1.76} = 4.84\,Y$	$X = 0.24\,Y^2$	$\frac{X^2}{6.8^2} + \frac{Y^2}{4^2} = 1$	$X^2 = 96.4\,Y$	$\frac{X^2}{3.6^2} + \frac{Y^2}{2^2} = 1$

Note: The bottom profile of the breast wall were obtained from Draft Code of IS 6934

Table. 2 Details of Orifice Spillway

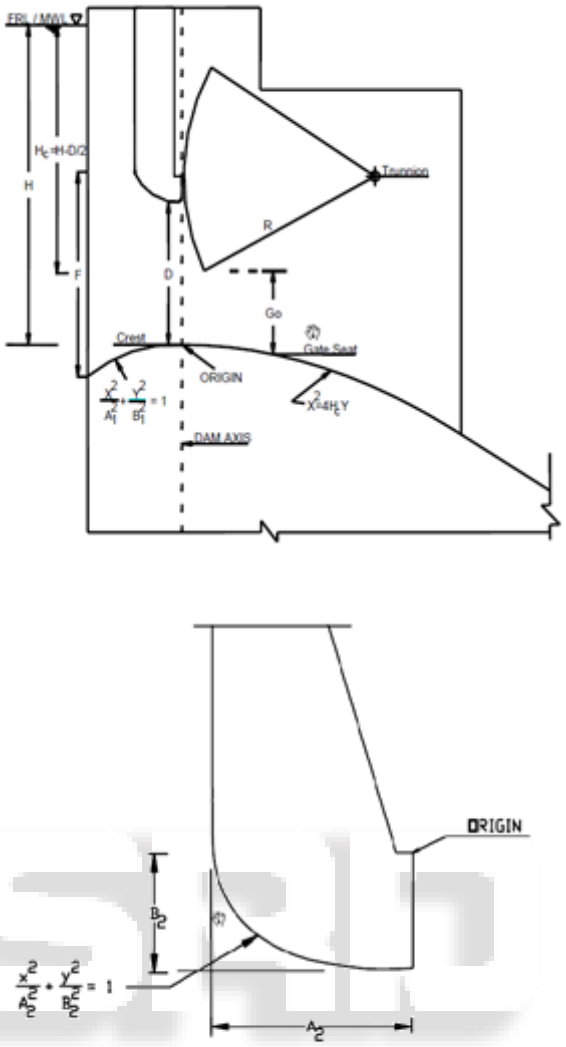
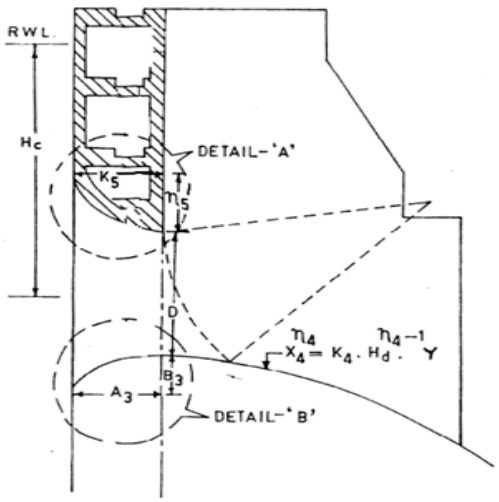


Fig. 1 Details of Orifice spillway (Acc. to Draft Code 2010)



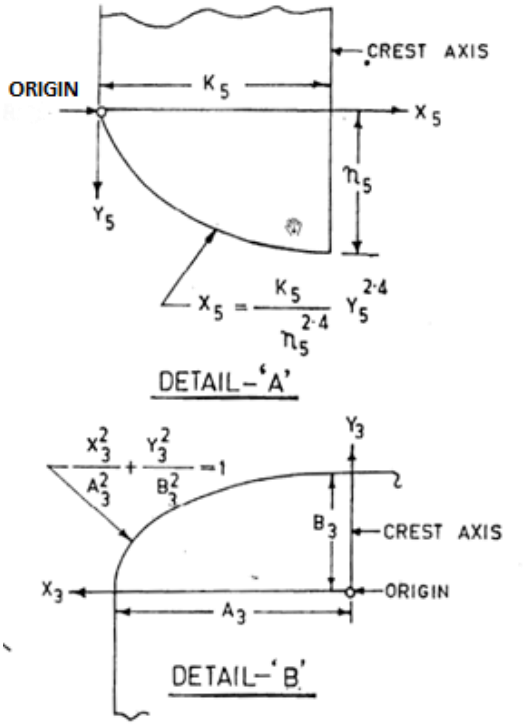
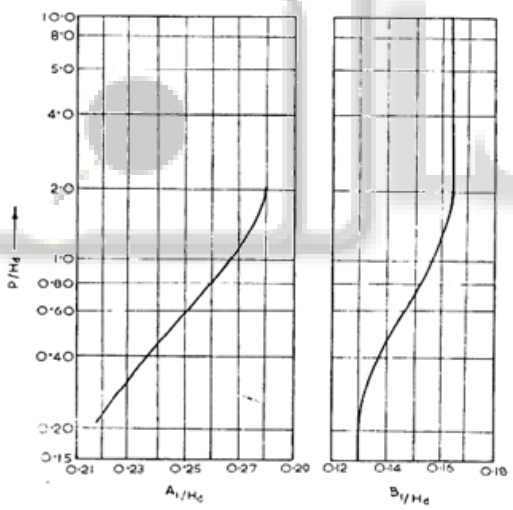


Fig 2 Details of Orifice spillway (Acc. To IS 6934:1973)



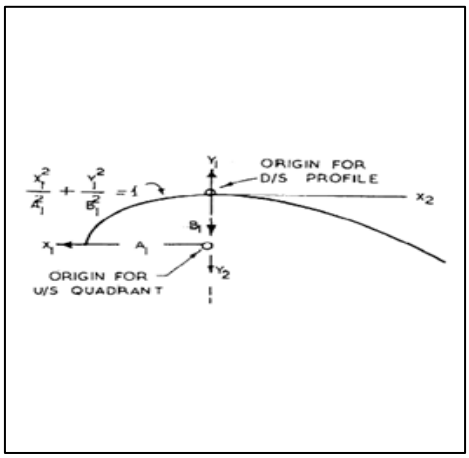
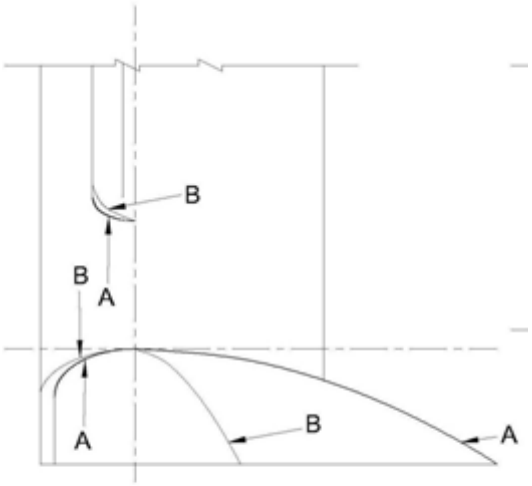


Fig.3 Orifice Spillway – Design parameters



A= design acc to draft code : 2010
B= design acc to IS 6934:1973

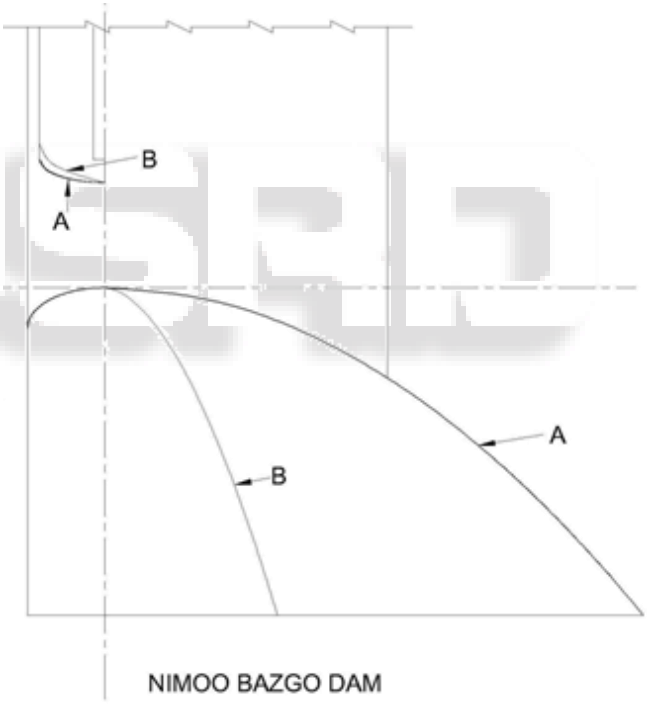


Fig. 4 Profile of Spillways